POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 31(1): 123–135, Y. 2016

COMPOSITION AND SEASONAL CHANGES OF LITTER ALONG THE SHORELINES OF SELECTED WATER BODIES IN WARMIA AND MAZURY REGION (NORTH-EASTERN POLAND)

***Tomasz Kajetan Czarkowski*[1], *Andrzej Kapusta*[2], *Krzysztof Kupren*[3], *Elżbieta Bogacka-Kapusta*[4], *Krzysztof Kozłowski*[5]**

[1] Warmia and Mazury Aquaculture Sp. z o.o.
[2] Department of Hydrobiology, Inland Fisheries Institute in Olsztyn
[3] Department of Tourism, Recreation, and Ecology
University of Warmia and Mazury in Olsztyn
[4] Department of Ichthyology, Inland Fisheries Institute in Olsztyn
[5] Department of Fish Biology and Pisciculture
University of Warmia and Mazury in Olsztyn

K e y w o r d s: rubbish, plastic, lake, tourism, recreational fisheries.

A b s t r a c t

Pollution of the shoreline of aquatic ecosystems, including inland water bodies, can pose a serious threat to the natural environment. The aim of this study were to quantify the spatial and temporal variation in anthropogenic litter abundance along 5 water bodies shore. This study examines the number, composition and seasonal changes in the litter found along the shores of selected water bodies in north-eastern Poland (the region of Warmia and Mazury). Water bodies and the shoreline fragments were selected for the study which represents different types of waters, lotic and lentic waters as well as those built by humans and natural ones. These water bodies are easily accessible to anglers from the shore and to hiking tourists and cyclists. Litter items were counted 3 times in 2013, before the tourist season, during the season and thereafter. The amount of litter along the shores of different water bodies differed, with the largest amounts being found along the Wadąg River (from 1172 to 1756 items ha^{-1}). However, the amount of litter found along the shorelines of the water bodies under study was not found to be season-dependent. The largest group of litter found along the shorelines was what can be included in the „other" category (from 23.1% to 38.1%), as well as plastic bags (from 15.1 to 24.0%), which can be particularly harmful to aquatic organisms. This study indicates that litter accumulated along the shores of water bodies in Warmia and Mazury is a considerable problem, which could create a barrier for further sustainable development of tourism and recreational fisheries in the region.

Address: Krzysztof Kupren, Department of Tourism, Recreation and Ecology, University of Warmia and Mazury in Olsztyn, ul. M. Oczapowskiego 5, 10-719 Olsztyn, Poland, phone: +48 (89) 524 56 04, e-mail: krzysztof.kupren@uwm.edu.pl

SKŁAD I SEZONOWE ZMIANY ZAŚMIECENIA LINII BRZEGOWEJ WYBRANYCH ZBIORNIKÓW WODNYCH W REGIONIE WARMII I MAZUR (PÓŁNOCNO-WSCHODNIA POLSKA)

***Tomasz Kajetan Czarkowski*[1], *Andrzej Kapusta*[2], *Krzysztof Kupren*[3], *Elżbieta Bogacka-Kapusta*[4], *Krzysztof Kozłowski*[5]**

[1] Warmia-Mazury Akwakultura Sp. z o. o.
[2] Zakład Hydrobiologii, Instytut Rybactwa Śródlądowego w Olsztynie
[3] Katedra Turystyki, Rekreacji i Ekologii
Uniwersytet Warmińsko-Mazurski w Olsztynie
[4] Zakład Ichtiologii, Instytut Rybactwa Śródlądowego w Olsztynie
[5] Katedra Biologii i Hodowli Ryb
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: śmieci, plastik, jezioro, turystyka, rybactwo rekreacyjne.

A b s t r a k t

Zanieczyszczenie linii brzegowej ekosystemów wodnych, w tym akwenów śródlądowych, może stanowić realne zagrożenie dla środowiska naturalnego. Celem niniejszej pracy było określenie przestrzennej i czasowej zmienności obfitości antropogenicznych śmieci wzdłuż brzegu 5 zbiorników wodnych. W pracy zbadano liczebność, skład, a także zmiany sezonowe śmieci występujących wzdłuż linii brzegowej wybranych zbiorników i cieków w północno-wschodniej Polsce (region Warmia i Mazury). Akweny i fragmenty linii brzegowej zostały tak dobrane żeby z jednej strony reprezentowały różne typy wód: płynące, stojące, sztuczne kanały oraz naturalne zbiorniki, z drugiej zaś, były łatwo dostępne dla wędkarzy łowiących z brzegu oraz turystów pieszych i rowerzystów. Śmieci liczono trzykrotnie w roku 2013, przed sezonem turystycznym, w środku sezonu oraz po sezonie. Ilość śmieci w linii brzegowej poszczególnych akwenów różniła się, a największą ich ilość znajdowano nad rzeką Wadąg (od 1172 do 1756 szt. ha^{-1}). Nie stwierdzono natomiast istotnego wpływu pory roku na ilość śmieci znajdującą się nad brzegami badanych zbiorników i cieków. Najliczniejszą grupę odpadów znajdowanych w linii brzegowej stanowiły śmieci zaliczone do kategorii „inne" (od 23.1% do 38.1%) oraz wykonane z tworzyw sztucznych torby foliowe (od 15.1 do 24.0%), które mogą być szczególnie niebezpieczne dla organizmów wodnych. Wyniki niniejszych badań sugerują, że zaśmiecenie linii brzegowej zbiorników i cieków na Warmii i Mazurach jest sporym problemem, który nierozwiązany może stanowić barierę dla dalszego zrównoważonego rozwoju turystyki i rybołówstwa rekreacyjnego w regionie.

Introduction

The problem of litter and the littering of waters and shore zones has been increasing since the 1950s, when plastics entered common use (CARPENTER et al. 1972, BARNES et al. 2009). Currently, the accumulation of litter in aquatic ecosystems is a growing problem around the globe (WETZEL et al. 2004). Litter in waters has an obvious effect on nature; microplastic is particularly harmful because it is eaten by many aquatic organisms, such as bivalves (CANESI et al. 2012), crustaceans (MURRAY and COWIE 2011), and fish (BOERGER et al. 2010).

Plastic pellets are worldwide contaminants that accumulate in the ocean, especially in sandy beaches (TURRA et al. 2014). The issue of littering waters and the coastal areas of seas and oceans has been explored more thoroughly than freshwater ecosystems (KORDELLA et al. 2013, HOELLEIN et al. 2014, NGUPULA et al. 2014). Most of the research studies have dealt directly with litter on the bottom, the water and the surface of seas and oceans (MOORE et al. 2001, KOUTSODENDRIS et al. 2008, BOERGER et al. 2010). There have been many studies on littering coastlines and beaches of salt water (CLAEREBOUDT 2004, MARTINEZ-RIBES et al. 2007, TOPCU et al. 2013) and relatively scarce reports on litter accumulated along the shorelines of inland waters (HOELLEIN et al. 2014, DRIEDGER et al. 2015).

Warmia and Mazury is a geographic and cultural region in the north-east of Poland, mainly in the lakeland; administratively, it lies within the province of Warmia and Mazury. The city of Olsztyn is the capital of the region and is the largest (population of about 180 thousand) city. Warmia and Mazury is a specific region of Poland, mainly because of its natural features. Of particular importance to the region are surface waters which occupy 138 566 ha, which is 5.7% of the area of the province of Warmia and Mazury and represents the highest proportion of water surface in the entire country (SZCZERBOWSKI 1995). The littering of beaches and coastal areas is one of the most visible manifestations of human activities in various aquatic ecosystems. For this reason, areas attractive to tourists may be particularly susceptible to such pollution (TURRA et al. 2014) and pollution caused by tourism appears to be increasing (GILBERT 2008). The touristic and recreational pressure in the area of Warmia and Mazury seems to be increasing; the number of guests in accommodation facilities in the years 2005–2011 increased from 760 to nearly 960 thousand (Statistical Office in Olsztyn 2012). The latest marketing activities aimed at promoting the region, including the „Mazury Cud Natury" („Mazury – a wonder of nature") campaign, have raised interest in the region. However, this also affects the deteriorating condition of the environment, especially the shoreline areas of lakes, rivers and other water bodies, which are major tourist attractions in the region (CZARKOWSKI et al. 2012, 2014). According to MAMCARZ and SKRZYPCZAK (2011), the development of tourism and recreation on waters in the north-east of Poland does not entail analysis of the pressure on the environment, which – together with uncontrolled promotion of the region and improper fisheries management – may bring negative effects by reducing regional biodiversity.

Surface water monitoring in Warmia and Mazury has been conducted for some time. This has included examination of the chemical condition, level of eutrophication, vascular plant condition, zoo- and phytoplankton, benthos, ichthyofauna, as well as physical and chemical properties of water. However,

no studies have been conducted on the amount and composition of litter left behind by people on the shores of inland water bodies in Warmia and Mazury. It seems that the litter left behind in the shore areas is becoming an increasingly serious problem in the lake districts, including Warmia and Mazury. It is well known that littered shoreline and beaches can repel tourists, thereby having a negative effect on tourism (KAI 2005). To deal with the problem effectively, it is necessary to determine the scale, components and the nature of the phenomenon, as well as its seasonal fluctuations. Therefore, it was decided to examine the extent of littering of the shoreline of selected water bodies in Warmia and Mazury over three study periods.

Materials and Methods

The study was conducted along fragments of the shoreline of 5 water bodies in Warmia and Mazury in the north-east of Poland, in the Province of Warmia and Mazury. These included the following bodies: Lakes Giławy, Łowne Duże and Ustrych, the Wadąg River and Kanał Węgorzewski (Węgorzewski Canal) (Figure 1, Table 1). Water bodies and the shoreline fragments were selected for the study which represent different types of waters, lotic and lentic waters as well as those built by humans and natural ones. These water bodies are easily accessible to anglers from the shore and to hiking tourists and cyclists. Moreover, it is noteworthy that Lake Ustrych is in the „Las Warmiński" Nature Reserve. A total of 4.73 km of shoreline was examined with an area of 4.70 ha (Table 1).

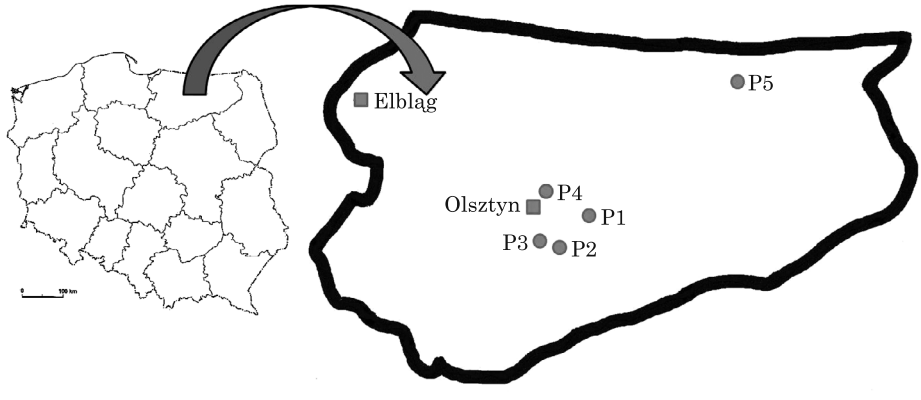

Fig. 1. Localization of studied water bodies in the Province of Warmia and Mazury: Lake Giławy (P1), Lake Łowne Duże (P2), Lake Ustrych (P3), Wądąg River (P4), Węgorzewski Canal (P5)

Table 1

Localization and characteristics of studied water bodies in Warmia and Mazury

Parameters	Lake Giławy	Lake Łowne Duże	Lake Ustrych	Wadąg River	Węgorzewski Canal
Latitude (°N)	53°42'44.04"	53°35'59.4"	53°38'12.89"	53°48'52.04"	54°12'21.35"
Longitude (°E)	20°49'2.44"	20°38'20.12"	20°29'46.53"	20°31'38.79"	21°43'45.8"
Shoreline length (m)	950	780	690	490	1820
Shoreline area (ha)	0.95	0.92	1.51	0.25	1.07
Distance from the city center (km)	26.2	22.5	15.5	3.7	0.8
Fished sites	16	16	7	28	59
Litter bins	0	0	0	0	9

Litter items were counted 3 times in 2013, before the tourist season (01–25.05; spring), during the season (11.07–02.08; summer) and thereafter (01–09.11; autumn). The litter was not collected to enable season-to-season comparisons, assuming that it was not only left behind, but it could also be collected by people for various reasons. Solid items were counted on the land while walking along the shore (the water/land junction) of the water bodies. The study zone was limited by a dirt road running in the immediate vicinity of the water. Since the belt in which litter items were counted was 4–12 m wide along the majority of the shoreline under study, the amount of litter was referred to as the area of the shore zone. The litter was classified into 10 groups: 1) empty packages of artificial lures; 2) empty packages and boxes of live and artificial bait; 3) small items of angling equipment and its packages; 4) plastic buckets; 5) empty cans of food and drinks; 6) plastic PET bottles; 7) empty glass alcohol bottles and other glass containers; 8) foil and plastic bags; 9) empty cigarette packets; 10) other (small paper pieces, food packages, tyres, air tubes and other rubber items). Piers and footbridges for anglers as well as other fishing sites and litter bins placed in the shore zone of the water bodies were also counted. The percentage of different categories (%) and the amount of different types of litter, expressed in absolute and relative numbers for different water bodies and between seasons, was also compared.

Statistical analysis

The statistical analysis was preceded by data transformation ($\log n+1$) and subsequent verification of homogeneity of variance with Levene's test. Subsequently, a two-way ANOVA was used to compare the amounts of litter in these categories across the aquatic ecosystems and seasons. *Post-hoc* analyses were conducted after statistically significant values of the F-test were achieved.

Tukey's test for a different number of variables was used to find statistically significant differences between the variables under study. The water bodies being examined were grouped by classification analysis. Data agglomeration was performed by the Ward method, using Euclidean distances as a measure of similarity. All statistical analyses were conducted with Statistica software (Statsoft Polska, Kraków).

Results

A total of 710 items of different kinds of litter were recorded before the tourist season along the shoreline of the water bodies under study. Debris densities not varied significantly between season ($P > 0.05$, Figure 2) whereas sites were significantly different from each other ($P < 0.05$, Table 2). A higher number of litter was observed in autumn. The highest amount was found along the Wadąg River and the lowest amount was along Węgorzewski Canal, both shoreline fragments had the largest number of identified angling sites, but the number of litter bins was completely different (Table 1). The number of litter items after the tourist season increased, reaching a total of 860. As in the previous periods, the highest amount of litter items was found on the Wadąg River and the lowest amount was found along Lake Łowne Duże.

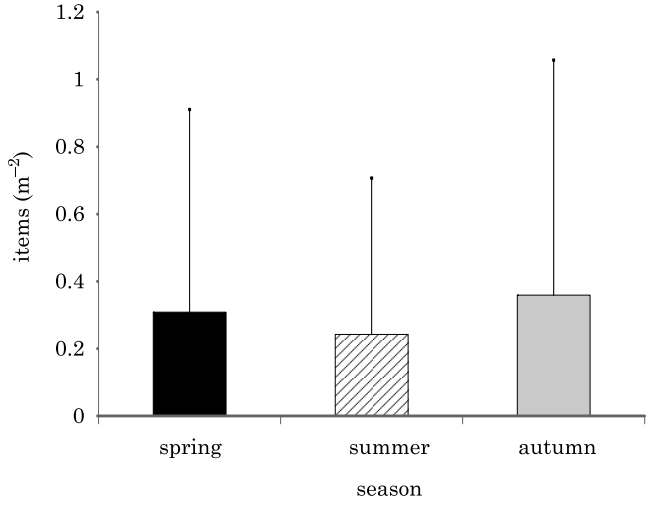

Fig. 2. Mean litter densities (± SD) in five water bodies in Warmia and Mazury during three seasons. SD – standard deviation

Table 2

Number (mean ± SD) of litter items per ha along the shorelines of selected water bodies. The mean values with the same letter index are not significantly different (ANOVA, $P<0.05$). SD – standard deviation

Litter category	Lake Giławy	Lake Łowne Duże	Lake Ustrych	Wadąg River	Węgorzewski Canal
Groundbait packages	$8.4^{b}\pm1.05$	$0.4^{b}\pm0.63$	$1.1^{b}\pm1.38$	$29.3^{a}\pm18.04$	$0.6^{b}\pm0.54$
Empty packages and boxes of lures	$13.0^{b}\pm2.19$	$4.0^{b}\pm3.32$	$5.5^{b}\pm0.76$	$122.7^{a}\pm34.02$	$1.6^{b}\pm1.94$
Small angling equipment	$1.4^{b}\pm0.61$	$0.7^{b}\pm0.63$	$0.2^{b}\pm0.38$	$25.3^{a}\pm23.44$	$0.6^{b}\pm1.08$
Plastic buckets	$1.1^{b}\pm0.01$	$3.3^{b}\pm1.09$	0.00	$8.0^{a}\pm8.00$	$0.3^{b}\pm0.54$
Cans	$11.2^{b}\pm2.65$	$13.4^{b}\pm8.44$	$7.7^{b}\pm1.91$	$108.0^{a}\pm63.50$	$9.7^{b}\pm3.89$
PET bottles	$12.3^{b}\pm0.61$	$5.1^{b}\pm2.26$	$2.6^{b}\pm1.15$	$244.0^{a}\pm97.73$	$5.0^{b}\pm3.78$
Glass bottles	$9.1^{b}\pm3.38$	$15.2^{b}\pm13.18$	$15.0^{b}\pm9.28$	$78.7^{a}\pm37.17$	$10.0^{b}\pm10.25$
Plastic bags	$27.0^{b}\pm20.37$	$9.1^{b}\pm3.49$	$13.0^{b}\pm3.40$	$350.7^{a}\pm46.88$	$12.8^{b}\pm6.76$
Cigarette packets	$3.9^{b}\pm1.61$	$2.5^{b}\pm1.25$	$2.4^{b}\pm1.38$	$48.0^{a}\pm0.01$	$4.7^{b}\pm1.87$
Other	$58.6^{b}\pm29.20$	$26.4^{c}\pm5.36$	$24.5^{b}\pm15.17$	$465.3^{a}\pm94.85$	$20.2^{c}\pm13.09$

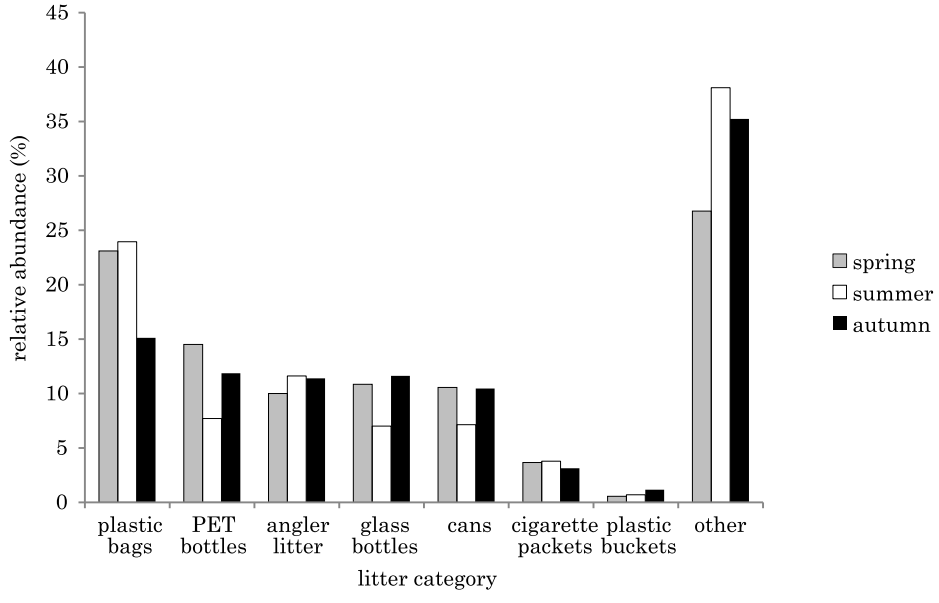

Fig. 3. Seasonal relative abundance of litter found on five water bodies in Warmia and Mazury

The number of litter items along the shoreline of different water bodies was significantly different ($P < 0.05$, Table 2). The highest amount of litter items was found on the Wadąg River (from 1172 to 1756 items ha^{-1}, Figure 2) and the lowest amount was along the Węgorzewski Canal (48.6–83.2 items ha^{-1}). The number of litter items at other sites was similar, except the „other" category ($P > 0.05$). The amount of litter found along the shorelines of the water bodies under study was not found to be season-dependent ($P > 0.05$).

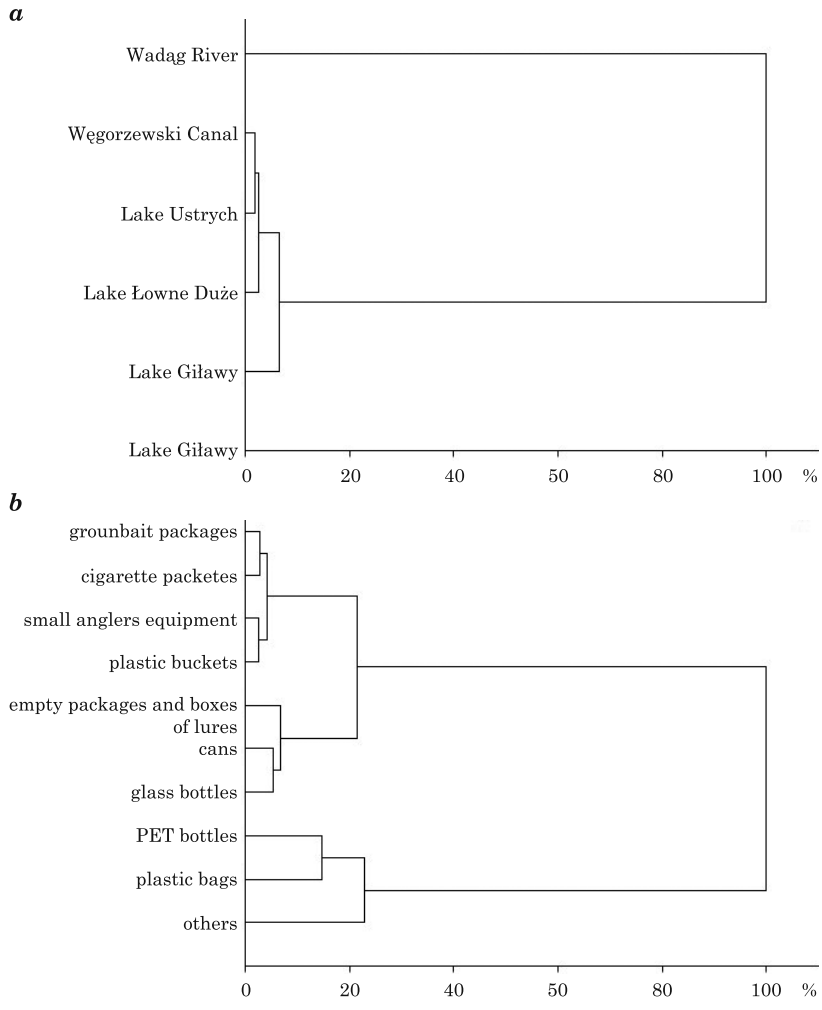

Fig. 4. The classification analysis for the sites (a) and categories of litter under study (b)

Litter classified as „other" accounted for the majority of waste at all the sites, before, during and after the tourist season; it accounted for: 23.1, 38.1 and 35.2% of all the litter (Figure 2). Moreover, high percentages of foil bags were recorded before and during the tourist season (23.1 and 24.0%, respectively). Angler litter accounted for a considerable portion of the rubbish during the tourist season (Figure 3). On the other hand, after the season the number of foil bags decreased (15.1%) and the number of plastic bottles increased (11.9%, Figure 3).

The analysis identified two clusters of the classification tree (Figure 4a). The first branch, considerably different than the other sites, was created by

the Wadąg River, whereas Lake Giławy stands out in the other part of the tree diagram. A comparative analysis of the waste (Figure 4b) shows that a separate branch of the tree diagram was made up of the litter classified as „other" as well as foil bags and PET bottles. These categories of waste accounted for between 50.7–71.6% of the litter. The smallest amount of litter in these categories was found along Lake Łowne and the largest amount was along the Wadąg River. In the other part of the dendrogram, the remaining categories of litter were grouped into two branches. One of them comprised bait boxes, cans and glass bottles, which accounted for from 20.9% of all the litter on the Wadąg River to 40.7% on Lake Łowne Duże. The other branch comprised the litter categories with the fewest items found along the shoreline of the water bodies. These included buckets, cigarette packets, fishing equipment and empty lure boxes. They accounted for 5.1% along the shoreline of Lake Ustrych and up to 10.1% on Lake Giławy.

Discussion

Depending on the season, the number of litter items found on the water bodies under study ranged from 710 to 860, along the total distance of 4.73 km of the shoreline, which is equivalent to 150.1 to 181.8 items km^{-1}. These findings, especially compared to the data obtained for the coastline of salt water bodies visited by tourists, can be regarded as positive because, for example, as many as over 130 items were found per one metre of the coastline in the Balearic Islands (MARTINEZ-RIBES et al. 2007). For comparison, the number of litter items along the coastline of the Baltic (the province of Pomerania) did not exceed 100 per km (GILBERT 2008), whereas 213.7 items per km were found along the shoreline of inland waters in the province of Saskatchewan, Canada (Great Canadian Shoreline Clean-up 2012). When the amount of litter is referred to a unit area, the results of this study are considerably different than those obtained on the beaches of Ghana by TSAGBEY et al. (2009), where much more litter was found.

Regardless of the season, the largest amount of litter was found on the Wadąg River, whose fragment under study lies within the boundaries of Olsztyn, a mere 4 km away from the city centre. Moreover, the number of accessible angling sites per 1 km of the shoreline (57.1) was larger than elsewhere. It appears that this may contribute to the higher level of shoreline littering. Although the area lies within the city boundaries, there are no litter bins. On the other hand, the amount of litter items found on the Węgorzewski Canal, which also lies within the town boundaries and is popular with both tourists and town inhabitants, was the smallest. Although the number of litter

bins along Węgorzewski Canal ranged from 7 to 9. No statistical differences were found between the amounts of litter during different seasons, but TOPCU et al. (2013) indicated distinct seasonal variability, because much more litter was found in autumn. Since the statistical analysis did not reveal any significant differences across seasons, litter appears to have been collected, not only left behind. Regular, coordinated cleaning of the shoreline was probably only done on the Węgorzewski Canal. Litter on other water bodies may have been collected, on a more or less individual basis, both by people collecting recyclable materials, as well as by more environmentally-aware fishermen, tourists or people living nearby.

During this study, different items were found along the shorelines which had been brought there by water. Most of them were packages which were left in the water after their contents had been used. As the analysis shows, the largest group of items included plastic objects (bags and bottles) and waste included in the „other" category, which were more difficult to classify specifically. These two categories of litter also dominated in the study conducted by MARTINEZ-RIBES (2007). In a study conducted recently on the Thames, plastic items, along with empty food and tobacco packages, also accounted for a considerable portion of the intercepted litter (MORRITT et al. 2014). The plastic waste, mainly bags and bottles, accounted for 61% of the litter along the Baltic coastline (Gilbert 2008). Plastic is regarded as one of the major agents polluting aquatic ecosystems, especially in salt waters (DERRAIK 2002, BARNES et al. 2009). Recently, it has been regarded as a potential threat to fresh waters; this applies mainly to the smallest plastic items. Plastic is a problem both in European lakes (FAURE et al. 2012) and the large American lakes (ZBYSZEWSKI and CORCORAN 2011, ERIKSEN et al. 2013). Plastic may have a negative impact on aquatic animals (fish, birds, mammals) because they may mistake plastic items for food and swallow them, which frequently ends up clogging their alimentary tract or poisoning them with toxins transmitted on plastic objects.

Inland recreational fisheries is becoming the main form of exploitation of wild freshwater fauna, both around the world (COWX et al. 2010) and in Poland (WOŁOS and DRASZKIEWICZ-MIODUSZEWSKA 2012, MICKIEWICZ 2013, LIRSKI and HRYSZKO 2014). Unfortunately, its negative effect on aquatic ecosystems, including the shore area, is becoming noticeable (COOKE and COWX 2006, ARLINGHAUS and COOKE 2009). One of the problems associated with recreational fisheries is the littering of the shoreline by anglers. The amount of litter left behind at sites of increased activity of anglers may be exceedingly large. For example, the amount of litter left behind by anglers during one season in a small marina (0.22 ha) situated about 20 km away from Olsztyn, on Lake Kośno, was 1311 items, with 313 empty bait and lure packages (CZARKOWSKI and KOZŁOWSKI unpublished data). This is why items of litter directly

associated with recreational fisheries (empty lure and bait packages, small items of fishing equipment and its packages, plastic buckets) were counted separately. Such typically angling-related litter accounted for up to 24.7% of all the litter found, depending on the water body and the season. In total, along all the fragments of the shoreline under study, litter accounted for from 10.6% before the season to 12.6% after the season, with a considerable contribution of bait and lure boxes and packages (up to 8.1% of the total amount). The total number of bait boxes per unit length of the shoreline under study ranged from 10.4 before the season to 13.3 items per km after the season. Compared with the Saskatchewan data, where the number of bait packages was close to 2.9 items per km (Great Canadian Shoreline Clean-up, 2012), the numbers recorded in Warmia and Mazury were much higher. In general, litter originating from angling activities may contribute considerably to the pollution of shores around the world (CLAEREBOUDT 2004, TOURINHO and FILLMANN 2011).

The amount of litter along the shores of different water bodies differed and the differences were statistically different. The largest amounts of litter were found on the Wadąg River. However, the amount of litter found along the shorelines of the water bodies under study was not found to be season-dependent. The largest group of litter found along the shorelines was what can be included in the „other" category, as well as plastic bags and PET bottles, which can be particularly harmful to aquatic organisms. This study indicates that littering along the shorelines of water bodies in the region of Warmia and Mazury is a considerable problem, which if left unsolved, could create a barrier to further sustainable development of tourism and recreational fisheries. However, more resources need to be allocated for research into the problem. It is necessary to develop appropriate solutions to prevent further degradation of the shore and the aquatic environment without entailing considerable financial outlays. This approach will be consistent with a sustainable lakeland development strategy.

Translated by JOANNA JENSEN

Accepted for print 31.12.2015

References

ARLINGHAUS R., COOKE S.J. 2009. *Recreational Fisheries: Socioeconomic Importance, Conservation Issues and Management Challenges*. [In:] Recreational Hunting, Conservation and Rural Livelihoods, Dickson, B., Hutton, J., & Adams W.M. (Eds), Science and Practice, Blackwell Publishing Ltd., Oxford, pp. 39–58.

BARNES D.K., GALGANI F. THOMPSON R.C., BARLAZ M. 2009. *Accumulation and fragmentation of plastic debris in global environments*. Philos. Trans. R. Soc. Lond. *B* Biol. Sci., 364(1526): 1985–1998.

BOERGER C.M., LATTIN G.L., MOORE S.L., MOORE C.J. 2010. *Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre.* Marine Poll. Bull., 60: 2275–2278.

Canesi L., Ciacci C., Fabbri R., Marcomini A., Pojana G., Gallo G. 2012. *Bivalve molluscs as a unique target group for nanoparticle toxicity*. Mar. Environ. Res., 76: 16–21.

Carpenter E.J., Anderso S.J., Harvey G.R., Miklas H.P., Peck B.B. 1972. *Polystyrene spherules in coastal waters*, *Science*, 178: 749–750.

Claereboudt M.R. 2004. *Shore litter along sandy beaches of the Gulf of Oman*. Marine Poll. Bull., 49: 770–777.

Cooke S.J., Cowx I.G. 2006. *Contrasting recreational and commercial fishing: Searching for common issues to promote unified conservation of fisheries resources and aquatic environments*. Biol. Cons., 128: 93–108.

Cowx I.G., Arlinghaus R., Cooke S.J. 2010. *Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters*. J. Fish. Biol., 76: 2194–2215.

Czarkowski T.K., Kupren K., Kogut B., Śnieg M. 2012. *Turystyka wędkarsko-rybacka jako znaczący element turystyki wiejskiej i agroturystyki*. [W:] Zrównoważone korzystanie z zasobów rybackich na tle ich stanu w 2011 roku. Wyd. IRS, Olsztyn, 171–179.

Czarkowski T.K., Kupren K., Kwasiborska D., Jaczewski J. 2014. *Woda i ryby jako znaczące elementy turystyki wiejskiej w województwie warmińsko-mazurskim*. Kom. Ryb., 4: 1–8.

Derraik J.G.B. 2002. *The pollution of the marine environment by plastic debris: a review*. Marine. Poll. Bull., 44: 842–852.

Driedger A.G., Dürr H.H., Mitchell K., van Cappellen P. 2015. *Plastic debris in the Laurentian Great Lakes: A review*. J. Great Lakes Res., 41: 9–19.

Boerger C.M., Lattin G.L., Moore S.L., Moore C.J. 2010. *Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre*. Marine Poll. Bull., 60: 2275–2278.

Eriksen M., Mason S., Wilson S., Box C., Zellers A., Edwards W., Farley H., Amato S. 2013. *Microplastic pollution in the surface waters of the Laurentian Great Lakes*. Marine Poll. Bull., 77: 177–182.

Faure F., Corbaz M., Baecher H., De Allencastro L.F. 2012. *Pollution due to plastics and microplastics in Lake Geneva and in the Mediterranean Sea*. Arch. Sci., 65: 157–164.

Gilbert C. 2008. *State of the Coast of the South East Baltic: An Indicators-Based Approach to Evaluating Sustainable Development in the Coastal Zone of the South East Baltic Sea*. Zakład Wydawnictw Instytutu Morskiego, Gdańsk.

Great Canadian Shoreline Clean-up. 2012. *Facts & Figures: Item Collection Highlights from2012*.(http://www.shorelinecleanup.ca/sites/default/files/gcscstaff/2012%20Facts%20and%20Figures%20Stats%20-%20Saskatchewan-EN_APPROVED.pdf (accessed July 10, 2015).

Hoellein T., Rojas M., Pink A., Gasior J., Kelly J. 2014. *Anthropogenic Litter in Urban Freshwater Ecosystems: Distribution and Microbial Interactions*. PloS one, 9: e98485. doi: 10.1371/journal.pone.0098485

Kai K. 2005. *Beach Litter in Amami Islands, Japan*. South Pacific Studies 26: 15–24.

Kordella S., Geraga M., Papatheodorou G., Fakiris E., Mitropoulou I.M. 2013. *Litter composition and source contribution for 80 beaches in Greece, Eastern Mediterranean: A nationwide voluntary clean-up campaign*. Aquat. Ecosyst. Health Manag., 16: 111–118.

Koutsodendris A., Papatheodorou G., Kougiourouki O., Georgiadis M. 2008. *Benthic marine litter in four Gulfs in Greece, Eastern Mediterranean; abundance, composition and source identification*. Estuar. Coast. Shelf Sci., 77: 501–512.

Lirski A., Hryszko K. 2014. *Akwakultura i rybactwo śródlądowe.* Rynek ryb, 21: 21–24.

Mamcarz A., Skrzypczak A. 2011. *Between the ichthyological biodiversity in the water bodies in Masuria (Mazury) and their management – theories, problems and hopes.* [In:] Fish Management in a Variable Water Environment. Jankun M., Furgała-Selezniow G., Woźniak M., Wiśniewska A.M (Eds.). Agencja Wydawnicza Argi SC R. Błaszak, P. Pacholec, J. Prorok., Olsztyn, pp. 7–34.

Martinez-Ribez L., Basterretxea G., Palmer M., Tintore J. 2007. *Origin and abundance of beach debris in the Balearic Islands*. Sci. Mar., 71: 305–314.

Mickiewicz M. 2013. *Economic effectiveness of stocking lakes in Poland.* Arch. Pol. Fish., 21: 323–329.

Moore C.J., Moore S.L., Leecaster M.K., Weisberg S.B. 2001. *A comparison of plastic and plankton in the North Pacific central gyre*. Marine Poll. Bull., 42; 1297–1300.

Morritt D., Stefanoudis P.V., Pearce D., Crimmen O.A., Clark P.F. 2014. *Plastic in the Thames*: *A river runs through it*. Marine Poll. Bull., 78: 196–200.

MURRAY F., COWIE P.R. 2011. *Plastic contamination in the decapod crustacean Nephrops norvegicus (Linnaeus, 1758).* Marine Poll. Bull., 62: 1207 –1217.

NGUPULA G.W., KAYANDA R.J., MASHAFI C.A. 2014. *Abundance, composition and distribution of solid wastes in the Tanzanian waters of Lake Victoria*. Afr. J. Aquat. Sci., 39: 229–232.

SZCZERBOWSKI J.A. 1995. *Rybactwo śródlądowe*. Wyd. IRS, Olsztyn.

TOPCU E.N., TONAY A.M., DEDE A., ÖZTÜRK A.A., ÖZTÜRK B. 2013. *Origin and abundance of marine litter along sandy beaches of the Turkish Western Black Sea Coast*. Mar. Environ. Res., 85: 21–28.

TOURINHO P., FILLMANN G. 2011. *Temporal trend of litter contamination at Cassino beach, Southern Brazil*. Journal of Integrated Coastal Zone Management, 11: 97–102

TSAGBEY S.A. MENSAH A.M., NUNOO F.K.E. 2009. *Influence of tourist Pressure on Beach Litter and Microbial Quality – Case Study of Two Beach Resorts in Ghana*. West African Journal of Applied Ecology, 15: 13–23.

TURRA A., MANZANO A.B., DIAS R.J.S., MAHIQUES M.M., BARBOSA L., BALTHAZAR-SILVA D., MOREIRA F.T. 2014. *Three-dimensional distribution of plastic pellets in sandy beaches: shifting paradigms*. Sci. Rep., 4 (4435). DOI: 10.1038/srep04435

WETZEL L., FILLMANN G., NIENCHESKI L.F.H. 2004. *Litter contamination processes and management perspectives on the southern Brazilian coast*. Int. J. Environ. Pollut., 21: 153–165.

WOŁOS A., DRASZKIEWICZ-MIODUSZEWSKA H. 2012. *Presja i połowy wędkarskie w jeziorach użytkowanych przez gospodarstwa rybackie w 2010 roku*. [W:] Zrównoważone korzystanie z zasobów rybackich na tle ich stanu w 2011 roku. Wyd. IRS, Olsztyn 55–64.

ZBYSZEWSKI M., CORCORAN P.L. 2011. *Distribution and Degradation of Fresh Water Plastic Particles Along the Beaches of Lake Huron, Canada*. Water, Air Soil Poll., 220: 365–372.